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Economic Cycles and the Responsiveness of Natural Gas Demand in China's Residential Sector

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Key Points

An important question for global gas markets is the extent to which China's demand for natural gas will grow, particularly in light of the perceived overbuild of liquefied natural gas (LNG) supply capacity. China's current 13th Five-Year Plan endorses the use of natural gas to reduce coal consumption and achieve a cleaner energy mix. In this paper we examine household natural gas demand, taking account of economic cycles, and provide insights relating to China's gas supply and demand balances that could have global consequences.

The plan formulated in the 8th National People's Congress in 1996 resulted in a longer cyclical upswing and an increase in urbanization and associated infrastructure development – the main focus of residential natural gas consumption.

Price reforms, income growth and increased infrastructure development all contributed to the rise in natural gas demand.

Natural gas demand is price sensitive and approximately income elastic. It is a preferred choice in China when accessible. Demand is still evolving and increases are unlikely to arise solely because of increased affordability through income growth or price reduction.

In addition to income growth, both environmental regulations aimed at suppressing coal consumption and government policies to foster natural gas accessibility by expanding infrastructure development are vital to achieving a cleaner energy mix.

Summary

Determining which factors drive the growth in gas demand is difficult because of data limitations and the non-convergence of short-term fluctuations to a long-term equilibrium. As a result, we use an unobserved components model (UCM) to estimate the responsiveness of residential demand for natural gas in urban China to changes in income and natural gas prices (i.e., estimate income and price elasticities), which made it possible to account for technological progress and periodically changing administered prices.

The Chinese economic cycle estimated here includes both the surge in economic growth in the early 2000s, and the decrease in the rate of growth and aggregate consumption due to investment slowdown since 2013. The cyclical components separating the two effects of China's five-year plans were modeled. These two effects reflect movements around both a steady state irrespective of economic growth and fluctuations around a growth trend.

During the sample period 2001 to 2014, the value of price elasticity is approximately -0.52 and the estimated value of income elasticity is not statistically different from unity, which suggests that natural gas for urban consumers tends to be a normal economic good that provides a high quality standard of living. That means it is regarded as neither a necessity nor a luxury good, reflecting the substitutability of natural gas. Demand for natural gas for heating purposes (cooking, water and space heating) is affected by changes in income and price. Coal is cheaper, so residents may choose it over natural gas. In urban areas where infrastructure exists, households will opt for natural gas; in other locations, coal use is the only possible choice. As more infrastructure is constructed, households will shift to natural gas. For those with access to natural gas, as their income increases, their consumption of gas for cooking and water heating will increase and/or they will move to larger accommodation where their consumption of gas for space heating will increase accordingly.

It is observed that the positive cyclical effect starting in the early 2000s, possibly triggered by the long-term plan of the 8th National People's Congress that resulted in an increase in urbanization and infrastructure development, contributed to higher natural gas consumption. The estimated midterm cycle reflects the 1999 trough in China's economic cycles and peak in 2012, which is in line with the economic slowdown that started in 2013. China's natural gas consumption declined following economic slowdowns in 2014 and 2015. This is in line with concerns over low consumption, investment and income growth as well as share of labor in income, discussed at the 18th National Party Congress in 2012.

This demonstrates that the model reasonably represents China's economy and residential demand for natural gas in urban areas. Accordingly, this derived cycle can also be considered as a business cycle indicator, which shows that information based on five-year plans and economic cycles is key to understanding China's economy and natural gas market potential.

The main findings of the research are:

- Natural gas is a normal yet substitutable economic good for urban households.

- The estimated midterm cycle suggests that China reached an economic cycle peak around 2012. This aligns with concerns, discussed during the 18th national party congress, over economic slowdown which likely contributed to the decrease in natural gas demand.

- Infrastructure investment to increase natural gas accessibility is essential for increased demand.

The Significance of China’s Residential Natural Gas Demand and Cycles

China’s 13th Five-Year Plan, which runs from 2016–2020, promotes the use of natural gas while authorities provide consistent regulatory support to boost gas consumption. The goal is to fulfill the dual objectives of the Energy Development Strategy Action Plan that forms part of the 13th Five-Year Plan: (a) to increase the share of natural gas in energy demand to at least 10 percent by 2020; and (b) to reduce coal consumption, thus decreasing pollution levels and achieving a cleaner energy mix.

China was the sixth-largest producer and third-largest consumer of natural gas in the world in 2014. It is a vital player in global energy markets, both as an importer and an investor (Ratner et al. 2016). Accordingly, the implications of China’s Energy Development Strategy Action Plan for 2014–2020 are unlikely to be limited to the domestic economy and could potentially have global spillover effects (Ratner et al. 2016; Paltsev and Zhang 2015).

Ratner et al. (2016) predict that China’s natural gas consumption in 2025 would be more than double that estimated for 2015. If demand does in fact grow at the rates required to achieve the announced targets in the 13th Five-Year Plan, natural gas imports and production and investments in infrastructure (i.e., shipping terminals, pipelines and power plants) must also increase. These changes will certainly affect both domestic investment and prospects for exporting hydrocarbons to China (Ratner et al. 2016). Foreign investment in the country’s energy sector and China’s investments abroad also will be affected (Tan 2013).

In the previous energy plan from the 12th Five-Year Plan, the target was for natural gas use to reach 7.5 percent of energy consumption in 2015. However, this target was not reached (Ratner et al. 2016).

To achieve the target set under the current plan, China’s government is encouraging the use of natural gas over substitutes such as coal (Li 2015). Authorities also wish to avert any repeat of the gas shortage that took place in 2015, which required the government to impose caps on residential users’ consumption (Li 2015).

The objective of this research is to examine China’s demand for natural gas and estimate price and income elasticities for the residential sector. Understanding the trends, variations and determinants of the demand for natural gas in China is vital to predicting the success of the 2020 plan and assessing its likely impact on both the Chinese and international economies, as well as the potential to export resources to China.

Chinese macroeconomic data are characterized by the coexistence of trend drifts and cyclical swings (Chang et al. 2015). Chang et al. (2015) explained that major Chinese economic reforms could potentially cause switching points in volatility and/or trend movements. According to Kwan (2010, 3), business cycles in China tend to be in tandem with the Communist Party Congress: “The Chinese economy has followed a five-year cycle in which the growth rate peaks in the year the Party Congress is held.” A five-year plan could trigger a longer cyclical swing, as with the 8th National People’s Congress in 1996, which passed a long-term plan to boost heavy industry (Chang et al. 2015). This long-term plan was associated with an increase in urbanization and infrastructure development, which contributed to greater natural gas consumption.

However, Yamasawa (2008) has differentiated between a classical cycle and a growth cycle. The former represents fluctuations around a steady state, regardless of economic growth, and the latter indicates fluctuations around a growth trend, where the furthest point from the high (low) signifies the peak (trough). Hence, it is important to account for short- and medium-term cycles in the model used so as to capture the fluctuations resulting from five-year plans and economic cycles.

Chang et al. (2015) noted a lack of empirical research on trends and cycles in China’s macroeconomy. Existing Chinese energy consumption studies are typically limited to primary energy consumption and electricity usage. According to Wang and Lin (2014), research on natural gas consumption in China is limited and has generally been qualitative. Wang and Lin (2014) have applied time series analysis and Yihua et al. (2014) have used unbalanced panel data to study national residential sector natural gas demand. This paper examines both natural gas demand and trend cycle decomposition in China.

Wang and Lin (2014) focused on the responsiveness of demand to changes in income and the price of natural gas and its substitutes, increased urbanization and climate change. They emphasized the importance of accounting for technological progress and recognized a need for data, which are currently unavailable, to estimate this component. They used annual data for urban China during the period 1985–2010 from the China Economic Information Center (CEIC), acknowledging that the data series are discontinuous. In Wang and Lin’s (2014) residential error correction model (ECM), the adjustment term is positive and insignificant, suggesting short-term fluctuations do not converge to a long-term equilibrium and there is no long-term relationship. Similarly, the results from our initial analyses – which include applying an ECM and a fully modified ordinary least squares (FMOLS) model – yield the same results. This shows that those methodologies are unsatisfactory, given the nature of the data. Consequently, a UCM model was chosen to deal with this issue and the data limitations.

Like Wang and Lin (2014), there is a focus here on urban China in examining residential consumption of natural gas. Natural gas demand in the residential sector has been rising rapidly since the mid-1980s (Higashi 2009; Yang et al. 2014). Residential energy consumption in China now ranks second behind the industrial sector, with most consumption taking place in urban residential areas because of the existence of urban pipeline networks (Wang and Lin 2014; Zhao et al. 2011; see Appendix A).

In the UCM model, a stochastic trend is allowed for that which will capture the effect of government policies, economic institutions, socioeconomic factors and technical progress. Short- and medium-term stochastic cycles are also included to account for the impacts of five-year plans and business cycles. Residential natural gas demand has been driven mainly by income growth, urbanization and low prices (Wang and Lin 2014). Due to limited availability of continuous time series data, CEIC data for the period 2001–2014 were used. CEIC is a comprehensive source of China’s macroeconomic data (Chang et al. 2015). Variables were used to capture the impact of changes in real price and real per capita income on per capita residential natural gas consumption. (For details on the UCM and precise variables employed, see Appendix B and C, respectively.)

Demand Responsiveness and Economic Cycle Estimation Results

A summary of the results of the economic cycle, and price and income elasticities estimation is provided in Appendix D.

Price and income responsiveness

The results show that the value of income elasticity of natural gas demand is positive and the value of price elasticity is negative. This reflects the fact that natural gas is a normal purchase for households in urban China. The estimated value of income elasticity is approximately 0.9, which is not statistically different from unity. Such a high income elasticity suggests that during the sample period, natural gas for urban consumers has come to be viewed as a comfort item that provides a good quality standard of living, but neither a necessity nor a luxury. The value of the estimated price elasticity is approximately -0.52. That is to say, a 1 percent increase in the price causes 0.52 percent decrease in consumption, suggesting that natural gas is rather price elastic. In other words, income and price elasticities of demand show natural gas does not represent an essential item for consumers in urban China.

Five-year-plan cycles: cycle 1

"China's goal process involves three overlapping five-year cycles: five-year plans, National Party Congresses and National People's Congresses … Under China's present political process, the two congresses have a reasonable sequence. The National Party Congress selects party leaders. After further negotiation, these leaders assume various governmental jobs in the following National People's Congress" (Xu 2011a, 772).

The period for this study is 2001–2014, which includes the 16th National Party Congress (October 2002–October 2007), the 17th National Party Congress (October 2007–November 2012), and part of the period relating to the 18th National Party Congress (November 2012) [The Communist Party of China 2017a, 2017b; Xu 2011]. It also covers the 10th National People's Congress (March 2003–March 2008), the 11th National People's Congress (March 2008–March 2013), and part of the period relating to the 12th National People's Congress (March 2013) [The National People's Congress 2017a, 2017b; Xu 2011].

The study period spans three five-year plans: the 10th Five-Year Plan (2001–2005), 11th Five-Year Plan (2006–2010), and most of the 12th Five-Year Plan period (2011–2015) [The authorized government portal site to China 2017; Louis Kuijs 2017; Xu 2011].

The three cycles are temporally misaligned (Xu 2011). For example, the National People's Congress lags behind the National Party Congress by a few months, so that "[a] new administration took full charge in March 2003 when the 10th Five-Year Plan had been going for two years" (Xu 2011, 772). For a five-year plan, preparations begin a few months prior to hearings and discussions at the government level; this stage goes on for a further few months before the five-year plan is ready. A third stage begins when ministries and sectors initiate their own plans, and central and local governments communicate. It takes another six to 12 months to mobilize implementation. In other words, a five-year plan involves preparation, mobilization and implementation stages. Thus, the actual time for implementation of the plan is less than five years (Chen 2017a). Since the implementation stage is shorter than five years, there is a lagged effect on households before a new five-year plan is announced. Also, since the cycles of the five-year plans, National Party Congresses and National People's Congresses overlap, the estimated 3.25-year duration of cycle 1 is justified.

Economic cycle indicator: cycle 2

After trough, the curve of cycle 2 initially grows at an increasing rate, then at a decreasing rate, and peaks in 2012 (see Figure 9c in Appendix D). In 1996, the Chinese government fundamentally changed institutional arrangements to strengthen heavy industry (Chang et al. 2015). According to Yamasawa (2008), April 1999 marks a bust in China's economic cycle: at that time the government switched to an expansionary fiscal policy. In November 1999, "a compromise was reached in China's bilateral trade negotiations with the United States, enabling China to join the World Trade Organization" (Yamasawa 2008, 16). This is consistent with the curvature of cycle 2 at the beginning of the study period.

The 18th National Party Congress, when discussing various policy goals in 2012, explicitly expressed concerns about low consumption growth and the low share of labor in income in China … Thus, China's macroeconomy faces twin problems:

- Low consumption and income growth.
- Overcapacity of heavy industries with rising debt risks" (Chang et al. 2015, 39).

This explains the movement in cycle 2 from 2012 to the end of the study period. The movement of the curvature at the beginning and end of the period captures the economic cycle in China during that period. The economic slowdown in China since 2013 is attributed to the slowdown in investment, which has been the engine of growth since 1997 (Chang et al. 2015). Vanderklippe (2015) and Wainberg et al. (2017) reported a decrease in China's natural gas consumption resulting from economic slowdowns in 2014 and 2015.

The results show that the average period of a short-term cycle (cycle 1) is 3.25 years. From this the four-year moving average of China's macroeconomic climate index (see Figures 9b and 10 in Appendix D) was calculated. The figure shows that the index and the associated moving average tend to follow the same movement and direction as cycle 2. Hence, the trend cycle decomposition of the natural gas consumption variable yields an economic cycle signal. It is important to note that consumption is a pro-cyclical and coincident indicator of economic cycles (Abel, Bernanke and Kneebone 2011).

Thus the model could be regarded as reasonably reproducing China's economy and residential natural gas demand in urban areas. This derived cycle can be considered as a business cycle indicator. This demonstrates that information derived from five-year plans and economic cycles is integral to the full understanding of China's economy and potential as an export market.

Conclusion

Gas exporters can take comfort that the market for natural gas in China is still developing. Household demand is increasing but is far from maturing. Natural gas may substitute for cheaper coal as it is preferred when accessible to households, even if it's more expensive. Government policies and measures to increase accessibility and affordability of natural gas and disincentivize coal consumption are collectively important to attain a cleaner fuel mix target. We can therefore expect continuing growth of natural gas supply and distribution infrastructure in China.

Appendix A: China's Residential Natural Gas Use – Stylized Facts

The residential sector's share of natural gas consumption increased from approximately 1 percent in 1980 to around 18 percent in 2016. "In China, urban areas share the most part of China's gas consumption" (Wang and Lin 2014, 545). Hence, the focus in this paper is on residential consumption of natural gas in urban China.

Urbanization, infrastructure development and city pipeline network construction have significantly fostered natural gas consumption growth (Wang and Lin 2014). Figures 3 to 5 and Table 1 show the increases in percentage of the urban population with access to natural gas at the national and city levels. Factors behind the increase in urban residential energy consumption include higher income, changes in consumer preferences and price competitiveness (Wang and Lin 2014; Zhao et al. 2011).

"Until the late 1980s, coal and coal gas were primary fuels even for city residents in the country. Then liquefied petroleum gas (LPG) became used for communal cooking and water heating fuel in several cities. Recently, natural gas use in urban areas has been growing rapidly, backed by the development of distribution infrastructure … natural gas use in

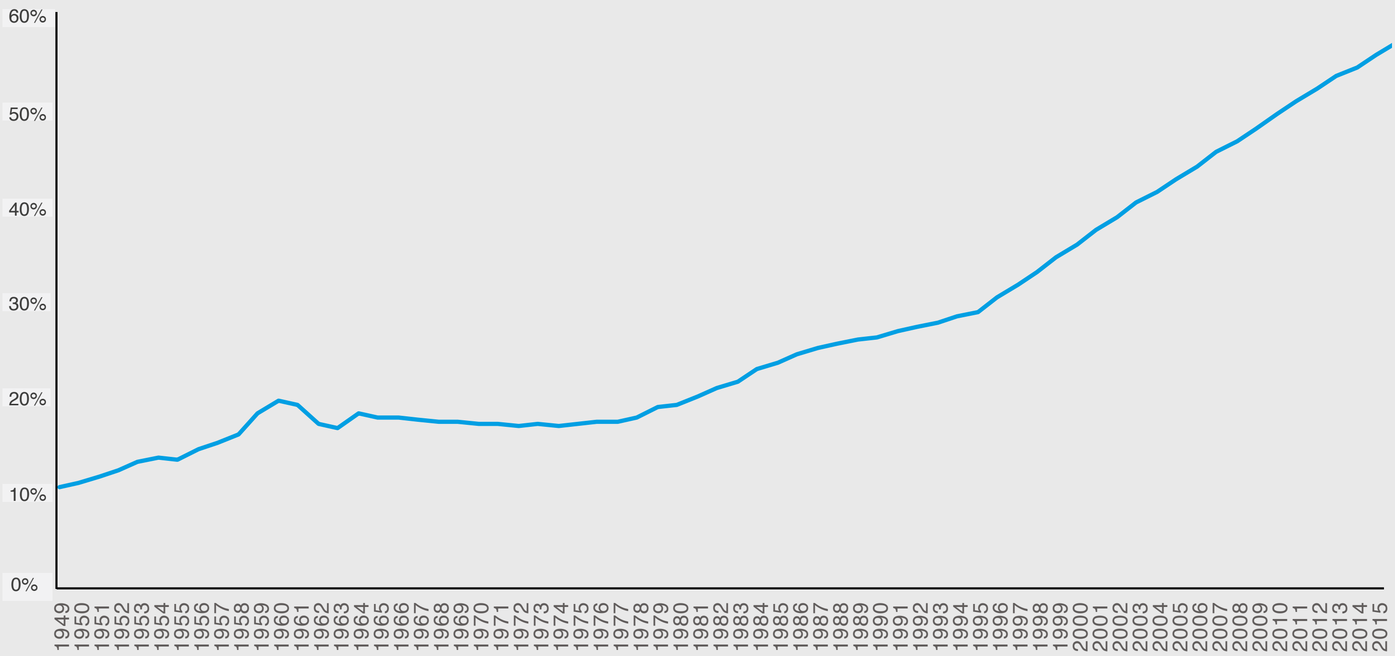

Figure 1. Ratio of urban population to total population (national).

Source: CEIC.

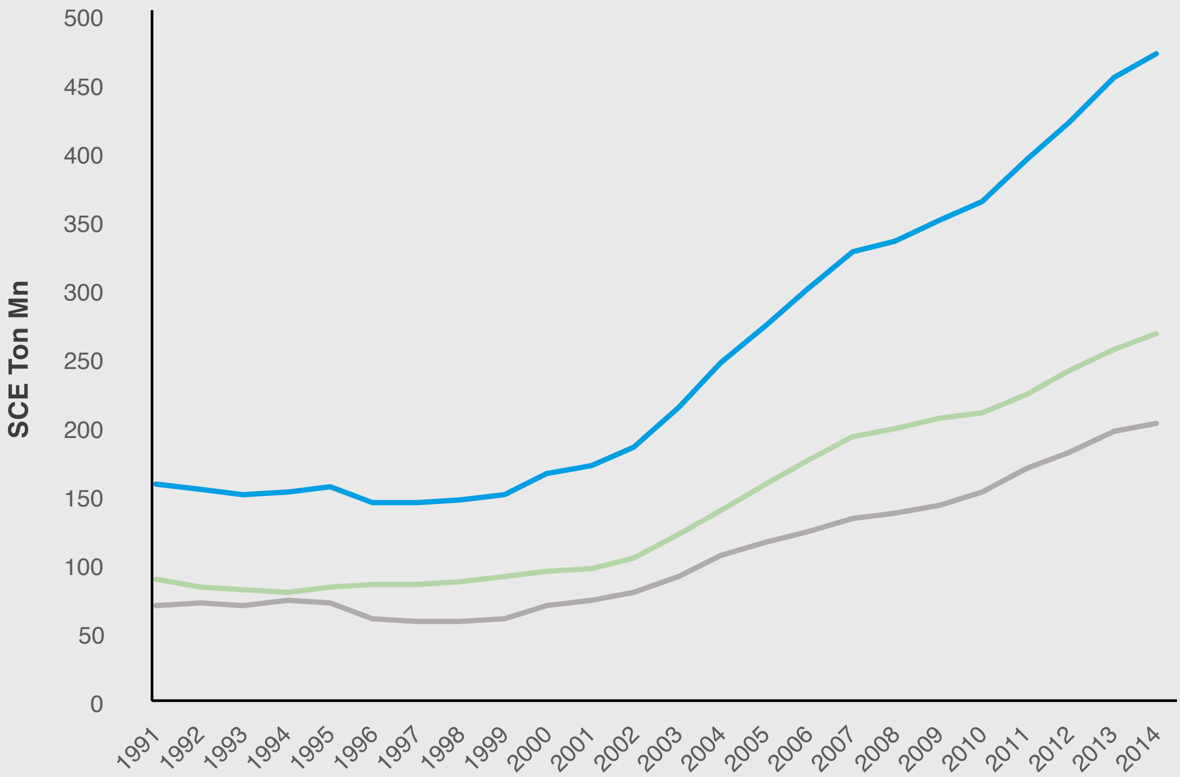

Figure 2. Total, urban and rural final energy consumption.

Source: CEIC.

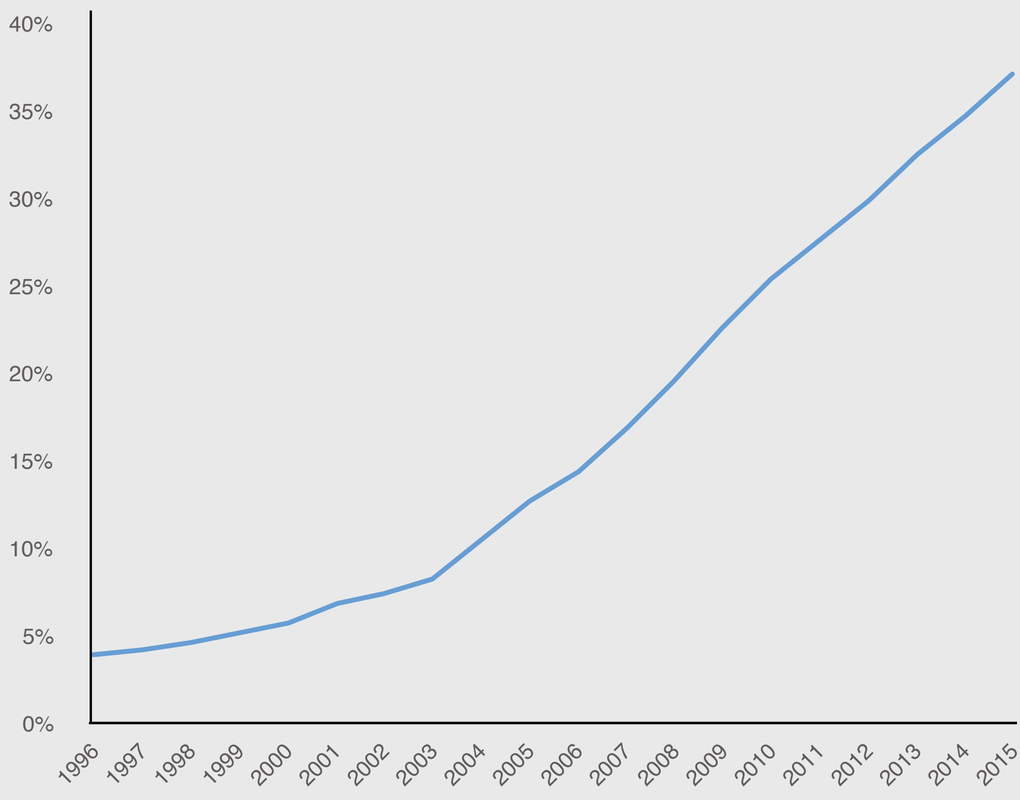

Figure 3. Ratio of urban population with access to natural gas to total urban population (national).

Source: Author's calculations using data from CEIC.

the residential sector has accelerated since 2005 because the natural gas price remained relatively cheap while the LPG price rapidly increased" (Higashi 2009, 14). "Natural gas consumption is increasing throughout China, particularly as a cooking fuel" (Yang et al. 2014, 13). "Residential gas use for cooking and water heating purposes (especially in large and medium cities) is prioritized in the National Gas Utilize Policy" (Li 2015, 12).

Possible measures of urbanization are: level of urbanization, which is measured as the ratio of urban population to total population; the rate of urbanization, which is the annual rate of growth

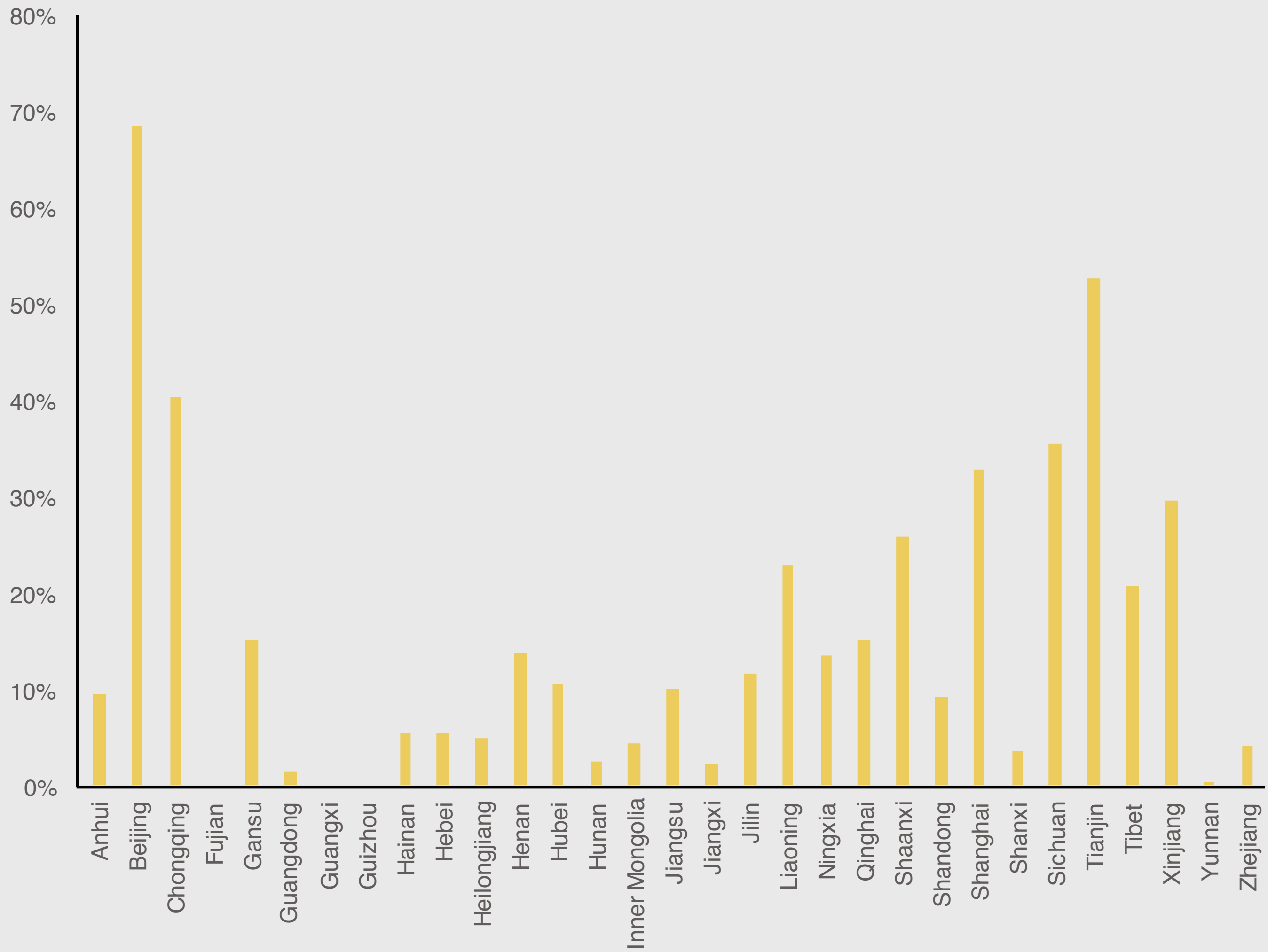

Figure 4. Percentage of population with access to gas: city – 2005.

Source: Author's calculations using CEIC urban population data and "Population with Access to Gas: City: Natural Gas".

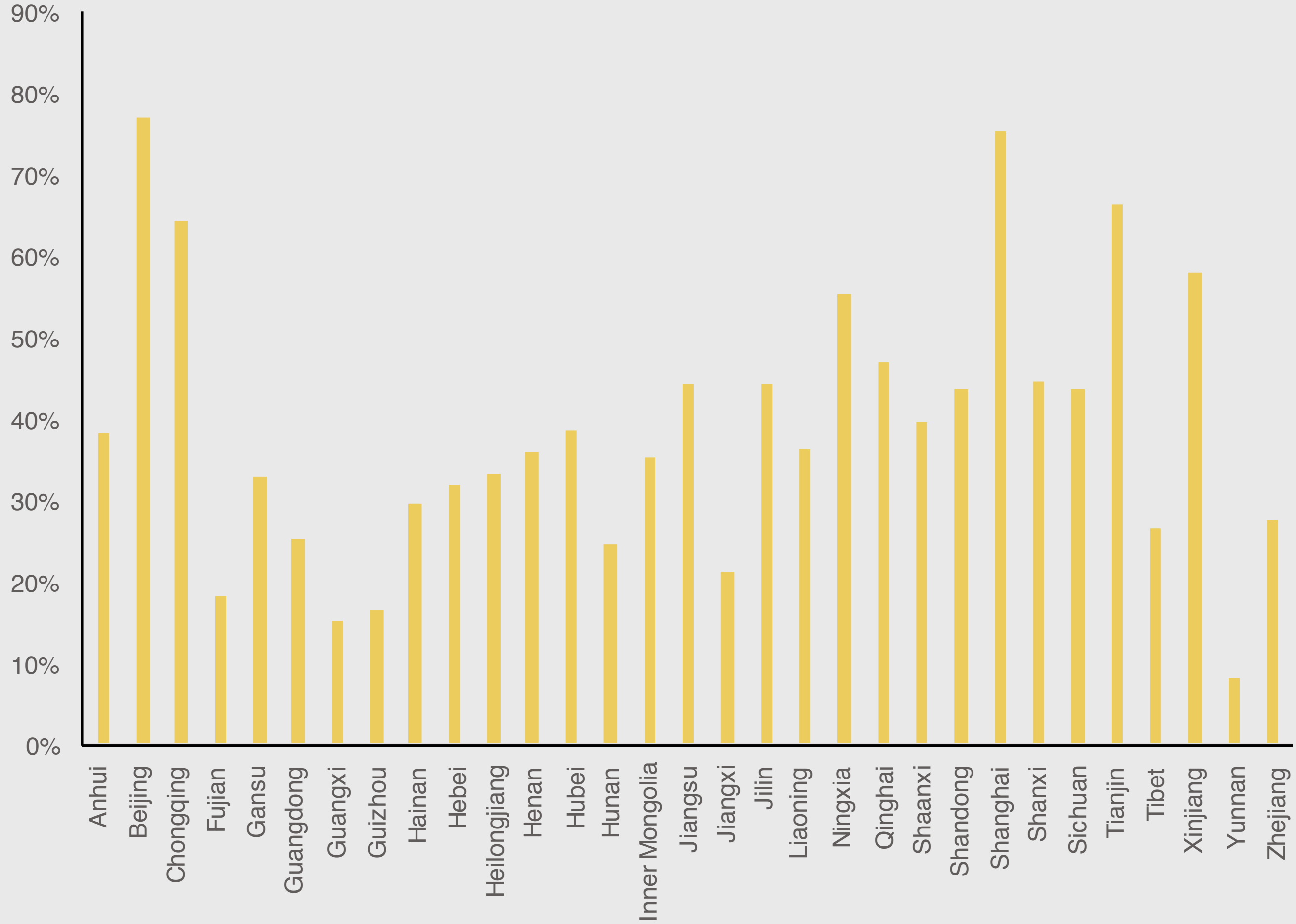

Figure 5. Percentage of population with access to gas: city – 2015.

Source: Author's calculations using CEIC urban population data and "Population with Access to Gas: City: Natural Gas".

of the urban population; the annual rate at which the level of urbanization is increasing; and rate of urban population growth minus the rate of rural population growth (United Nations 1974). Urbanization can also be measured by gas population, which reflects the percentage of the population with access to natural gas. The latter is employed in the analysis here, calculated as the ratio of urban population with access to natural gas to the total urban population (Wang and Lin 2014). The CEIC series 3740601 (CBVHIH) and 3731601 (CBVGH) are used to compute the percentage of the population with access to natural gas in Figures 4 and 5 and Table 1.

Appendix A: China's Residential Natural Gas Use – Stylized Facts

Table 1. Percentage of population with access to natural gas: national and city levels.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
National	3.94%	4.20%	4.59%	5.09%	5.62%	6.74%	7.34%	8.25%	10.37%
Anhui									
Beijing	10.12%	14.04%	20.26%	24.91%	27.93%	32.83%	44.45%	46.73%	62.16%
Chongqing		30.68%	29.78%	29.61%	32.41%	33.46%	35.17%	37.29%	37.68%
Fujian									
Gansu					0.26%	9.51%	10.25%	12.12%	11.85%
Guangdong									
Guangxi					0.00%				0.09%
Guizhou	0.14%	0.16%	0.16%	0.19%	0.21%	0.33%	0.32%	0.18%	0.16%
Hainan							7.00%	20.33%	13.39%
Hebei					1.79%			3.82%	4.84%
Heilongjiang	1.54%	1.65%	1.93%	2.04%	2.82%	3.01%	3.54%	4.21%	4.42%
Henan	7.57%	7.63%	8.00%	8.19%	8.44%	10.11%	10.04%	10.78%	12.34%
Hubei				0.45%	0.01%	0.09%	0.21%	0.28%	0.59%
Hunan									
Inner Mongolia								2.63%	3.61%
Jiangsu								0.29%	4.99%
Jiangxi						8.88%		0.01%	0.83%
Jilin	1.15%	1.57%	1.66%	2.69%	3.28%				
Liaoning	18.00%	18.45%	18.47%	20.15%	21.55%	22.31%	22.74%	23.24%	28.85%
Ningxia				0.23%	0.75%	3.20%	4.09%	7.75%	11.31%
Qinghai		1.16%	1.64%	1.76%	2.19%	2.63%	3.01%	3.83%	14.71%
Shaanxi					10.71%	12.44%	16.12%	18.33%	23.87%
Shandong	0.90%	1.28%	1.37%	1.74%	2.57%	3.77%	5.81%	7.96%	8.77%
Shanghai				3.37%	6.79%	13.91%	14.72%	17.30%	36.12%
Shanxi		0.47%	1.31%	3.39%	3.06%	3.31%	3.75%	2.44%	3.35%
Sichuan									
Tianjin	33.48%	34.02%	45.92%	51.76%	57.11%	65.02%	68.37%	71.22%	72.75%
Tibet									
Xinjiang	0.01%	0.01%	0.01%	1.30%	4.32%	8.84%	15.36%	21.35%	27.00%
Yunnan			0.45%	0.08%	0.20%	0.19%		0.39%	0.39%
Zhejiang								0.47%	2.24%

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
12.64%	14.27%	16.81%	19.50%	22.54%	25.41%	27.54%	29.79%	32.53%	34.67%	37.04%
9.58%	10.65%	13.87%	17.55%	20.51%	24.85%	29.40%	32.75%	33.82%	36.23%	38.15%
68.54%	71.77%	72.53%	74.22%	76.63%	76.63%	76.66%	76.63%	76.63%	76.68%	76.99%
40.27%	41.57%	47.03%	49.05%	49.48%	56.27%	53.69%	55.66%	55.13%	60.07%	64.22%
0.00%	0.21%	1.15%	1.90%	11.34%	13.02%	13.30%	13.19%	15.12%	15.95%	18.23%
15.11%	16.40%	17.53%	18.52%	21.00%	21.43%	23.20%	25.23%	26.60%	27.59%	33.10%
1.41%	1.43%		9.62%	13.92%	13.35%	14.72%	16.17%	19.14%	22.20%	25.29%
0.03%	0.50%	2.30%	3.19%	4.66%	5.75%	6.86%	9.17%	11.43%	12.18%	15.40%
0.17%	0.40%	0.81%	0.80%	0.91%	0.99%	1.95%	4.32%	9.77%	9.83%	16.72%
5.65%	6.71%	8.23%	13.53%	15.16%	17.90%	20.49%	22.93%	23.47%	26.32%	29.61%
5.50%	7.29%	11.41%	19.42%	22.27%	26.57%	27.83%	28.78%	30.01%	28.23%	31.85%
5.11%	5.59%	6.61%	13.64%	24.11%	26.61%	27.74%	29.23%	30.55%	32.64%	33.32%
13.88%	14.57%	14.60%	17.26%	19.75%	22.94%	24.43%	27.44%	31.71%	33.97%	35.81%
10.71%	11.80%	15.09%	19.25%	23.19%	24.63%	27.46%	30.57%	34.99%	36.29%	38.55%
2.63%	6.14%	8.04%	8.78%	11.97%	14.82%	14.92%	18.15%	19.94%	22.93%	24.68%
4.40%	9.35%	12.36%	13.29%	13.82%	18.81%	20.43%	24.15%	31.28%	33.86%	35.43%
10.17%	14.67%	17.25%	20.19%	23.97%	27.44%	31.85%	34.95%	37.46%	40.94%	44.21%
2.41%	2.73%	3.44%	4.92%	5.96%	8.04%	12.63%	15.05%	19.45%	20.76%	21.36%
11.70%	13.72%	12.52%	12.98%	14.79%	19.79%	24.46%	26.21%	28.43%	35.70%	44.44%
22.87%	24.98%	25.83%	27.42%	28.82%	29.32%	30.36%	33.20%	35.01%	33.82%	36.18%
13.54%	16.45%	20.36%	24.73%	29.51%	35.89%	40.21%	43.09%	52.23%	53.08%	55.33%
15.33%	28.42%	31.50%	35.32%	35.79%	35.36%	37.93%	39.87%	43.93%	43.62%	46.85%
25.92%	24.49%	26.31%	26.43%	29.26%	32.04%	33.53%	34.32%	36.91%	38.64%	39.70%
9.17%	13.95%	17.36%	22.01%	26.90%	30.33%	33.16%	36.74%	39.87%	42.34%	43.72%
32.95%	36.38%	42.26%	44.26%	49.98%	53.15%	58.72%	62.14%	66.88%	71.50%	75.35%
3.56%	4.76%	11.07%	18.60%	22.73%	25.11%	28.50%	31.56%	40.29%	42.12%	44.50%
35.68%	32.26%	33.19%	33.49%	34.08%	36.00%	38.14%	39.33%	40.99%	42.32%	43.52%
52.55%	58.74%	70.00%	64.79%	59.47%	55.80%	54.83%	55.29%	53.92%	61.83%	66.28%
20.81%		0.00%		0.00%	0.00%	0.00%	0.00%	6.70%	10.04%	26.69%
29.54%	35.11%	37.45%	41.44%	44.44%	47.66%	50.99%	55.77%	59.79%	59.38%	58.13%
0.37%	0.37%	0.40%	0.42%	2.10%	2.31%	1.58%	1.80%	1.99%	5.61%	8.24%
4.34%	6.68%	10.37%	11.96%	15.32%	16.48%	18.91%	20.33%	23.88%	26.23%	27.56%

Source: Author's calculations using CEIC urban population data and "Population with Access to Gas: City: Natural Gas".

Note: Empty cells indicate data are not available.

Appendix B: Econometric Methodology

The UCM technique chosen here decomposes a series into latent components – e.g., stochastic trend and cycle – and overcomes non stationarity, small sample and data irregularities issues. It also handles structural changes (Brintha et al. 2015). The components of a UCM model reveal the mechanism underlying the movements within a series and provide a set of diagnostic tools for model assessment. Broadstock and Hunt (2010), Bernard et al. (2006) and Hunt et al. (2000, 2003a, 2003b) explained that estimating the underlying energy demand trend by allowing a stochastic trend captures the effect of exogenous factors such as socioeconomic factors, technological advancements and technical progress. According to Guangrong and Yanjun (2011, 1178), state space modeling is useful for modeling changes in "government policy and economic institutions." The UCM methodology is useful given the nature of available data for residential sector natural gas demand and pricing regime in China.

The aim of this study is to estimate the price and income elasticities of natural gas demand in China's urban residential sector. Employing a UCM model enabled non stationarity and data limitation issues to be addressed. Allowing for a stochastic trend enabled the effect of changes in government policies, economic institutions, socioeconomic factors and technical progress to be captured. Moreover, incorporating stochastic cycles allowed effects of the five-year plans and business cycles to be taken into account. It is important to incorporate cycles when examining trends so as to capture possible turning points (Diego J. Pedregal 2017). According to Chang et al. (2015), Chinese data are characterized by trend drifts and cyclical swings. Trend cycle decomposition is tricky when using a short time series because trend distinctions from low frequency fluctuations could become blurred since they may be a part of cycle in a longer time series (Meko 2017). STAMP software was employed to carry out the analysis. In this Appendix, the model applied to examine natural gas demand is discussed. For more details on the UCM and Kalman filter, refer to Baum (2013), Commandeur et al. (2011), Dilaver and Hunt (2010), Durbin (2004), Harvey (2002), Koopman et al. (2009), Pelagatti (2015), Stata (2015) and PennState (2017).

The UCM decomposes the natural gas demand variable into stochastic trend, regression effects and cycles components. These components capture features of series that reveal their behavior and movements. Conditional on the estimates of the hyper parameters and frequencies that are of the maximum likelihood, the decomposition of unobserved components (Koopman et al. 2006) can be observed. UCM models follow the state space modeling framework, where unknown parameters are estimated via a likelihood function that uses one step ahead predictions errors generated by Kalman filter and is maximized by an iteration process. The Kalman filter utilizes current and past observations to estimate components (refer to Harvey 2002 for details).

Modeling the natural gas demand variable by a UCM is shown here by Equations 1–3.

$$y_t = \mu_t + \pi x_t + \Psi_t + \varepsilon_t \tag{1}$$

Equation 1 is the observation equation where:

y_t: dependent variable, which is the logarithmic level of natural gas demand,

μ_t: stochastic trend,

πx_t: regression component,

x_t: a set of regressors, which are the logarithmic level price of natural gas and income variables,

π: a vector of fixed parameters,

Ψ_t: cycle(s) component, and

ε_t: irregular that has a 0 mean and constant variance, $\varepsilon_t \sim NID(0,\varepsilon_\eta^2)$. It is also referred to as model disturbance or idiosyncratic shock.

The stochastic trend is specified as follows:

$$\mu_t = \beta_t + \mu_{t\text{-}1} + \eta_t \qquad \eta_t \sim NID(0,\sigma_\eta^2) \tag{2}$$

$$\beta_t = \beta_{t\text{-}1} + \epsilon_t \qquad \epsilon_t \sim NID(0,\sigma_\epsilon^2) \tag{3}$$

Equations 2 and 3 are state equations where:

μ_t : is the stochastic level,

η_t: level disturbance that has a 0 mean and constant variance,

β_t: stochastic slope, and

ϵ_t: slope disturbance that has a 0 mean and constant variance.

ε_t, η_t, and ϵ_t are mutually uncorrelated.

σ_η^2 and σ_ϵ^2 are referred to as hyper parameters, where larger hyper parameters reflect greater stochastic movements in the trend.

The ratio of each variance to the largest of them is called the signal-to-noise ratio (or q-ratio). A low q-ratio (close to 0) implies insignificance of the underlying variance.

The inclusion of a stochastic or deterministic slope, and the choice of the specification of the stochastic trend depends on the feature of the variable examined. Unit root tests of the demand, price and income variables used in the analyses were performed to decide on the appropriate specification. Graphical inspection and unit root tests imply the variables are generally non-stationary (integrated of order one). Hence, in this analysis a stochastic level is included, excluding the slope. STAMP employs the diffuse initialization of the non-stationary state variables (Koopman et al. 2009).

In addition, the stochastic cycles Ψ_{1t} and Ψ_{2t} were included to model the five-year plans and economic cycles effects. The latter is of order 2 to allow for more smoothness of the economic cycle while still permitting it to be stochastic. A cyclical component could be incorporated to account for serial autocorrelation in the idiosyncratic shock. Also, a simple random walk model could be expanded to include “a stationary cyclical component that produces serially correlated shocks around the random walk trend” (Baum 2013, 43; Harvey 2002; Harvey et al. 2004; Koopman et al. 2009; Pelagatti 2015). Therefore, similar to Baum (2013), the idiosyncratic shock was omitted and instead stochastic cycles included. Accordingly, a model that includes a random walk trend, two stochastic cycles (one first order and one second order), and price and income variables, was estimated; this is illustrated by equations 4-5.

$$D_{NG,t} = \mu_t + \Psi_{1t} + \Psi_{2t} + \pi_p Price_t + \pi_I Income_t \tag{4}$$

$$\mu_t = \mu_{t-1} + \eta_t \tag{5}$$

where $D_{NG,R,t}$ is natural gas demand, μ_t is the stochastic level, Ψ_{1t} is the short-term cycle to capture the five-year plans effect, Ψ_{2t} is the medium-term cycle to capture the economic cycle effect, $\mu_t+\Psi_{1t}+\Psi_{2t}$ is the stochastic cyclical trend, and $\pi_p\, Price_t+\pi_I Income_t$ is the regression effect.

Appendix C: Data

Sample period

The sample period studied was 2001 to 2014. Data on the price variable start in 2001, which restricts the time sample. Despite data availability limitations, 2001 was considered an adequate starting point. First, China was not a major natural gas consumer until the early 2000s (Wainberg et al. 2017). Second, according to Chang et al. (2015), trends and cycles in China reflect changes in the fundamentals of China's economy and institutional arrangements since the late 1990s. In particular, changes were triggered in March 1996 when the 8th National People's Congress passed a long-term (15-year) plan to adjust industrial structure to strengthen heavy industry. The effects of this plan would propagate through the economy with a lag. Other reforms and important economic events since the mid-1990s include the start of privatization in November 1997, trade liberalization and membership in the World Trade Organization (WTO) in November 2001, end of explicit pegging of yuan to the U.S. dollar in July 2005, the U.S. financial crisis in September 2008 and China's government fiscal stimulus in 2009 and 2010 (Chang et al. 2015). The sample period ends in 2014 due to data availability issues.

Variables

Residential demand for natural gas has been driven mainly by income growth, urbanization and low prices (Wang and Lin 2014). The analysis here focuses on estimating the responsiveness of urban residential demand for natural gas to changes in price and income (see Appendix A). Data that would enable urban and rural demand for natural gas to be separated are unavailable. However, as discussed in Appendix A, residential demand for natural gas is primarily in urban China. Using data from CEIC: (a) [Figure 6] the ratio of "Natural Gas Consumption:

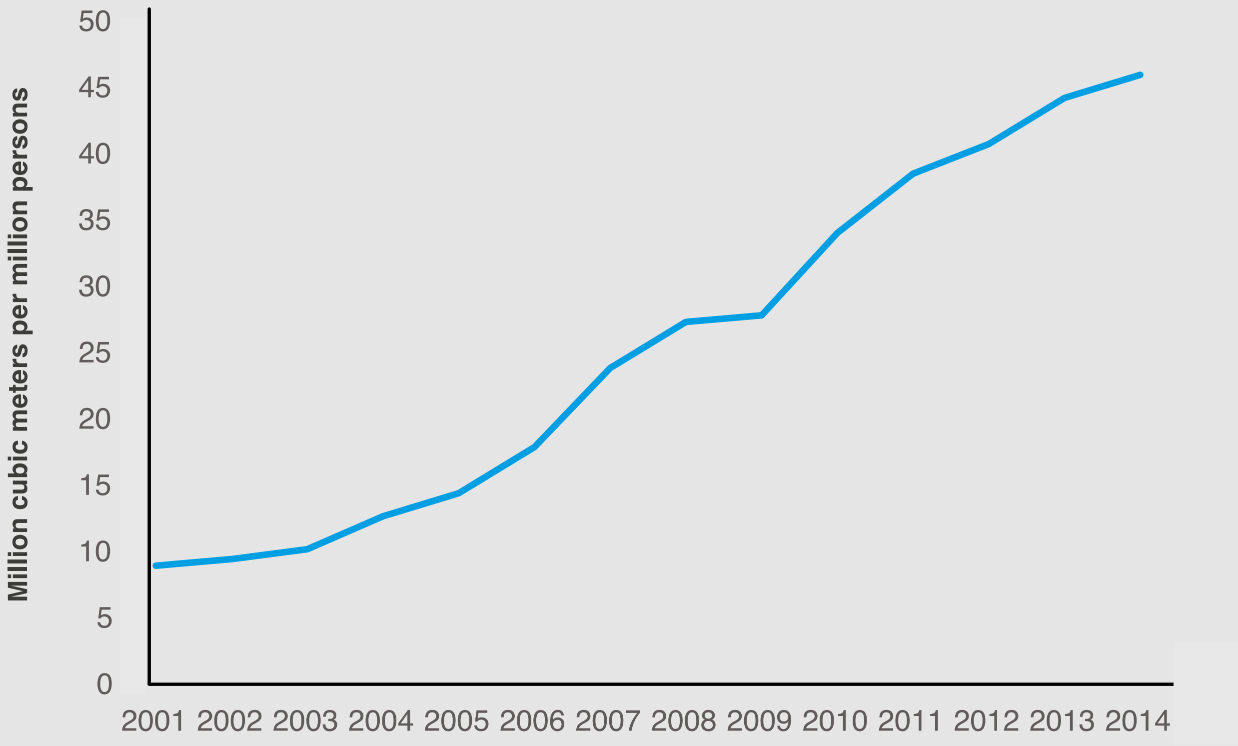

Figure 6. Per-capita natural gas consumption.

Source: CEIC.

Residential" to the urban population as a measure of per-capita residential consumption of natural gas in urban China is calculated; (b) [Figure 7] "Disposable Income per Capita: Urban" is used as a measure for income and deflated by the urban retail price index; and (c) [Figure 8] "Service Price: 36 City Average: Pipe Natural Gas: for Resident" is employed as the price variable and deflated by the urban consumer price index.

Statistical tests, along with the graphical inspection of Figures 1-3, imply that the variables do not revert to a long-term equilibrium. Further analysis using an error correction model (ECM) and a fully modified ordinary least squares (FMOLS) model reveal the absence of a long-term relationship between the variables, where short-term fluctuations do not converge to a long-term equilibrium. A UCM model was applied to deal with this issue.

Empirical issues

There were difficulties in finding variables with consistent frequencies and updated series; moreover, there is a general lack of information, e.g., variable definitions and methodologies used to estimate and manipulate data that would enable figures from different sources to be compared. Chang et al. (2015) documented the same issues. Sources consulted include International Energy Agency (IEA), Oxford

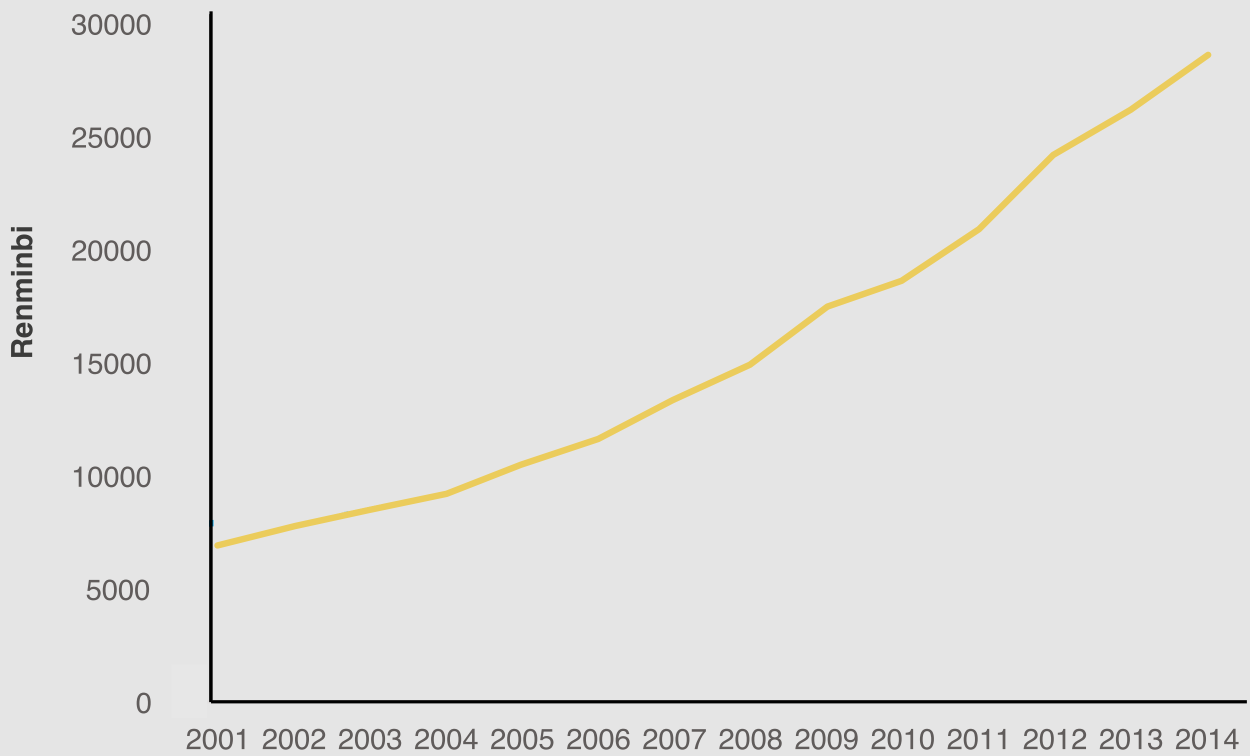

Figure 7. Per-capita real disposable income.

Source: CEIC.

Appendix C: Data

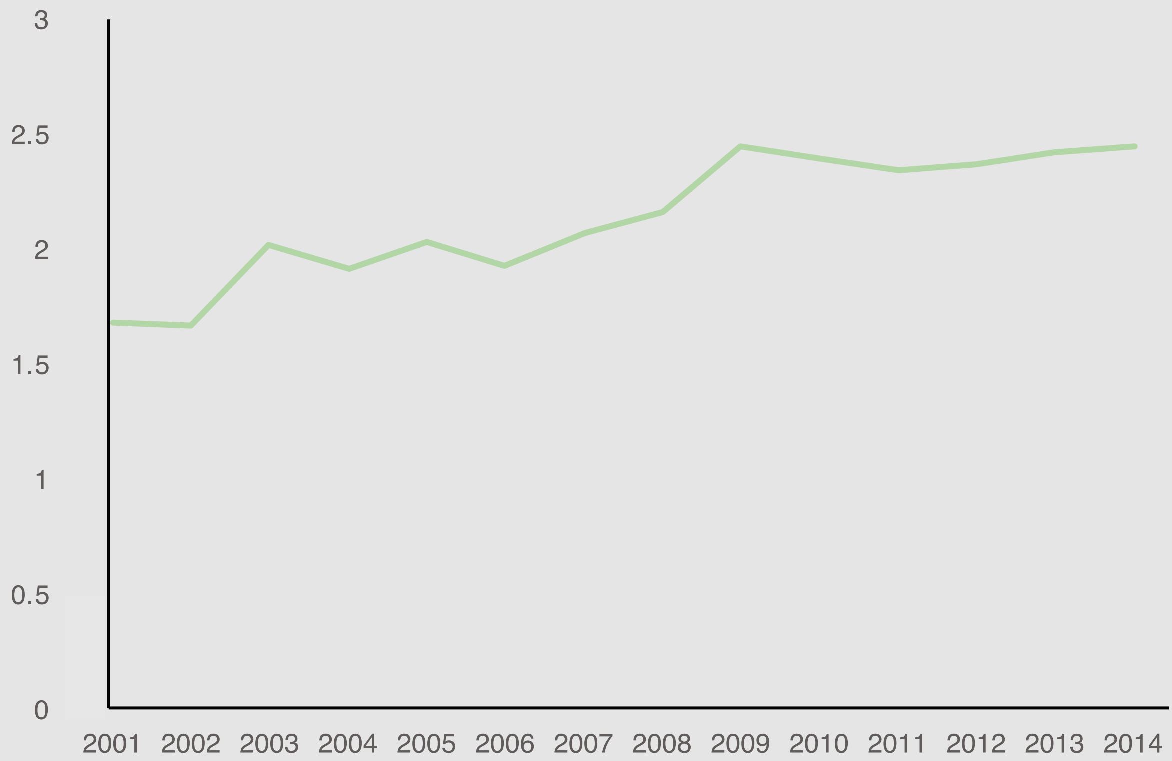

Figure 8. Real price of natural gas.

Source: CEIC.

Database, Organization for Economic Co-operation and Development (OECD), CEIC, China's Statistics Yearbook (various editions), U.S. Energy Information Administration (EIA), SIA Energy, Facts Global Energy (FGA), Bloomberg and Thomson Reuters Eikon.

One of the objectives of this research is to estimate the price elasticity of demand. Annual data on demand for natural gas and possible substitutes are available from the 1980s, monthly data on prices of natural gas and substitutes are available at the earliest from 2001 and semi-annual data on sales prices are available from either 1998 or 2000. Historical data on prices before 2001, and/or quarterly or monthly data on demand for natural gas and substitutes, starting at least in 2001, unfortunately are not available.

CEIC has monthly data for the price of residential sector natural gas beginning in 2001. CEIC also has data for the price of liquefied petroleum gas (LPG), which is a substitute for natural gas, but only from 2006. The price data from the Oxford database pertain to the producer price index (PPI), and are useful in the analysis of the industrial sector. Including these variables in the model could capture changes in the economy, but not the responsiveness of residential sector end-users to prices they pay. The CEIC also has monthly diesel price data available, beginning in 2007, which are useful for estimating transportation demand though not residential demand.

CEIC data on average sales prices of natural gas by China National Offshore Oil Corporation (CNOOC), PetroChina Company Limited (PTR) and China Petroleum and Chemical Corporation (CPCC) are semi-annual and start in either 1998 or 2000. In some cases, those sales prices are the prices industrial entities pay, but not the exact prices paid by the residential sector. Including those sales prices in a model for the residential sector would capture some changes in the economy, which could be beneficial, but would not show the responsiveness of residential sector end-users to the exact prices they pay. In other words, it would be advantageous to have the exact prices paid by households.

In short, the annual consumption data begin in 1985 and the monthly price data start in 2001. If more data had been available, the linearized version of the almost ideal demand system (LAIDS) could have been applied so as to estimate price elasticity for natural gas as well as its substitutes and income elasticities of demand. Still, a stochastic trend could have been incorporated in the model to deal with non-stationarity and account for exogenous factors such as periodically changing prices, tastes and technical progress. Instead, the annual average of the available price data was calculated and used together with the consumption and income variables to estimate the price and income elasticities. Some movements in the price variable are washed out by averaging. In this context, quarterly data would be preferable to annual data. However, consumption and population data are only available on an annual basis. Population data are needed to calculate per-capita variables if they are not readily available from a data source. Given these data availability issues, annual data for the period 2001–2014 were used to estimate income and own price elasticities.

Appendix D: Estimation Results

The coefficient of determination based on differences Rd^2 shows that the regression effect explains 83 percent of the movement in demand (Table 2). The Rd^2 is more useful than coefficient of determination R^2 when the series has trend movements. The q-ratios imply the variation in the underlying energy demand trend (UEDT) is driven by the stochastic level, economic cycles and five-year plans, respectively (Figure 9). These results are robust to different variation of the model that are elaborated on in A. Razek, N. (2017), the detailed version of this paper.

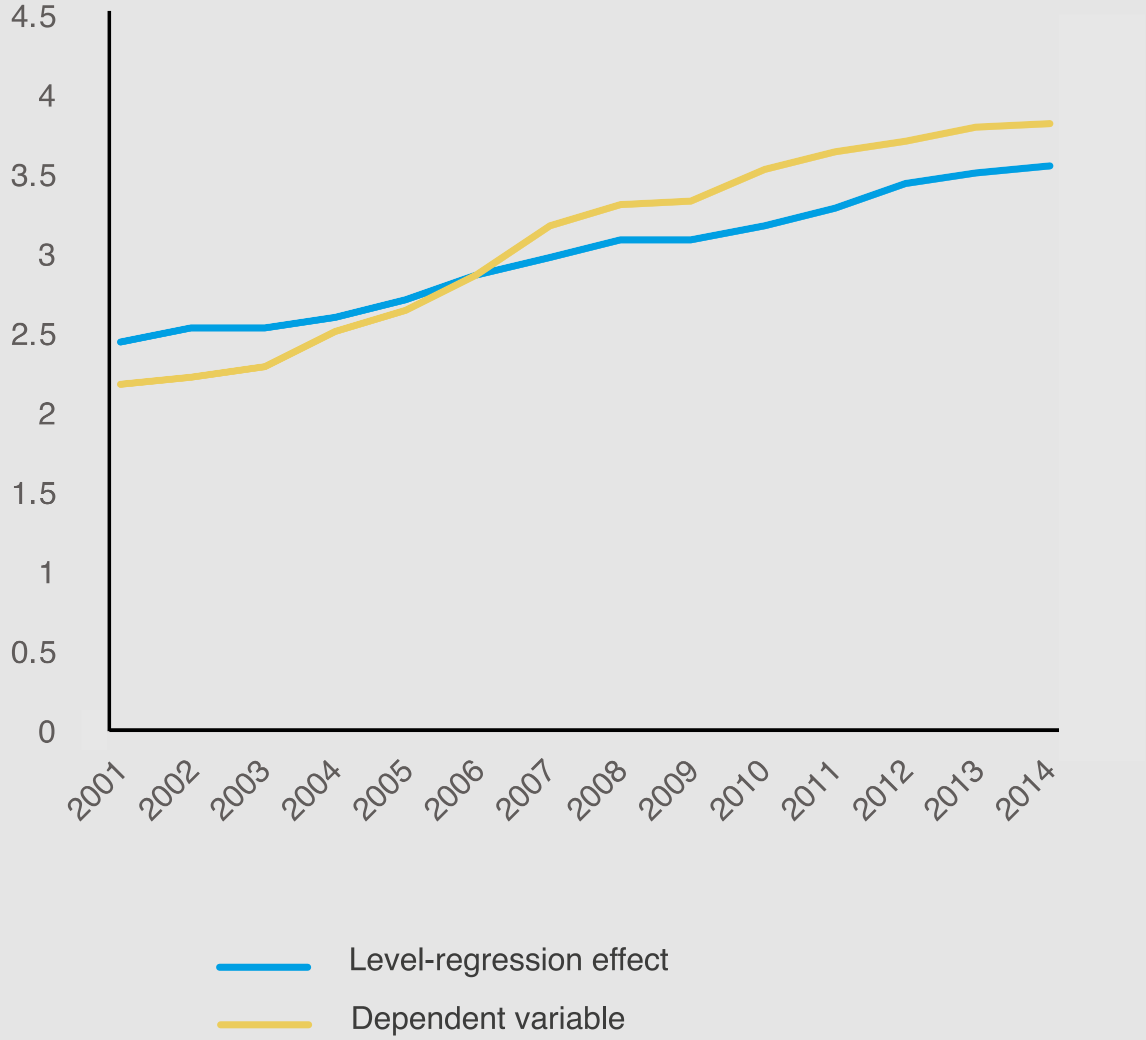

Figure 9a. UCM results.

Source: Estimation results.

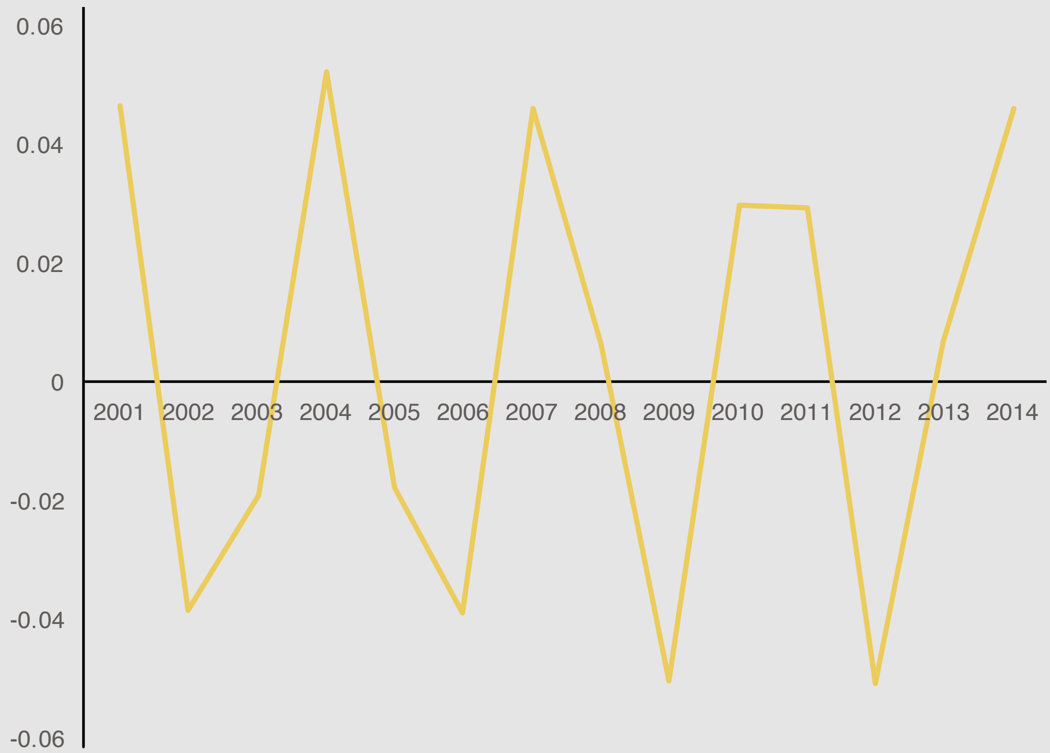

Figure 9b. UCM results (cycle 1).

Source: Estimation results.

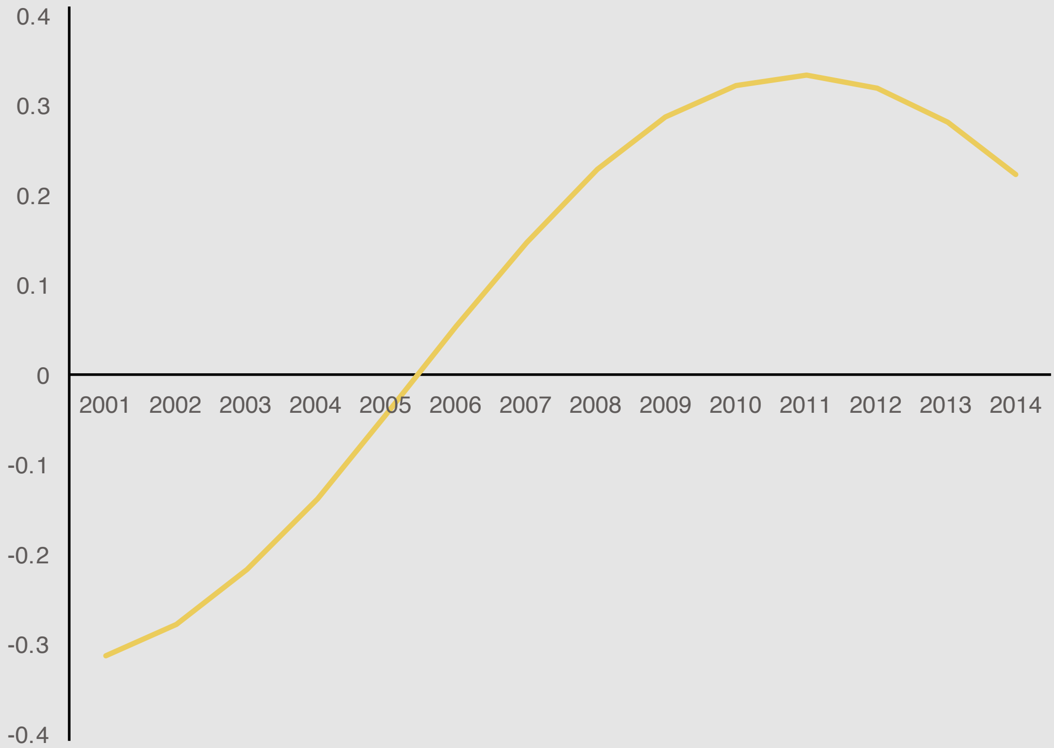

Figure 9c. UCM results (cycle 2).

Source: Estimation results.

Appendix D: Estimation Results

Table 2. Regression effects in final state at time 2014.

Regression effects in final state at time 2014	Log of real disposable income	Log of real price
Coefficient	0.91959	-0.51631
t-value	3.99592***	-3.01338***
Cycle 1 – period	**3.24659**	
Cycle 2 – period	**24.02665**	

Source: Estimation results.

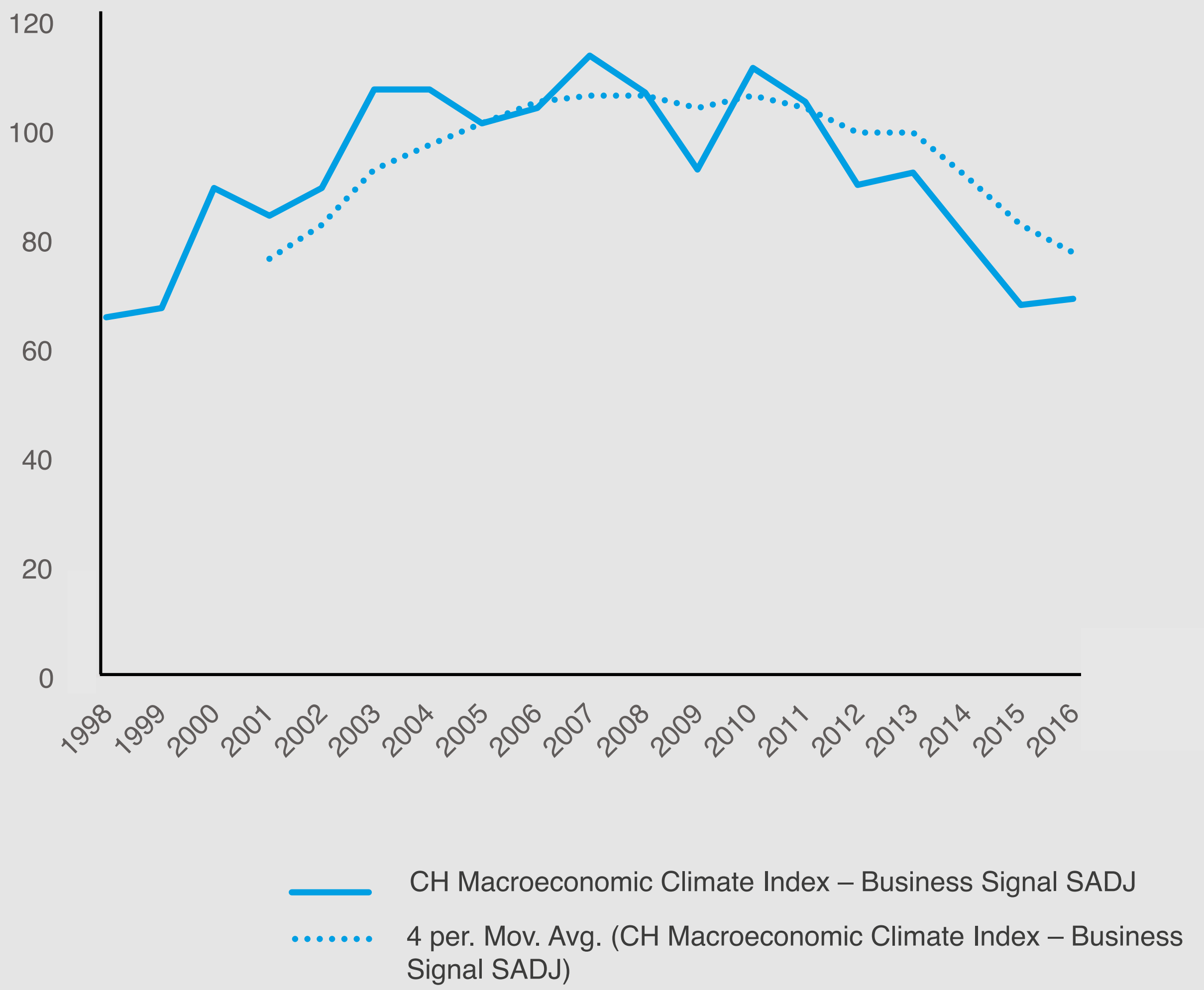

Figure 10. China business cycle signal – index.

Source: DataStream.

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Notes

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About the Project

KAPSARC Energy Model – China (KEM-China)

This project contains two parts: KEM-China supply and KEM-China demand. The objective of the project is to provide insight into the Chinese energy economy and to understand how economic and policy drivers influence China's fuel mix and interaction with global energy markets. In relation to the Saudi Vision 2030, the project aims to comprehend the potential of China as an export market and as an investor for Saudi Arabia, and derive policy recommendations to maximize the benefits of Saudi Arabian-Chinese economic agreements. KEM-China demand focuses on quantifying the determinants of demand for oil and natural gas on a sectorial level.

KAPSARC

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